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ENERGY RECOVERY FROM DRYERS

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MANITOBA/CANADA CONSERVATION AND RENEWABLE ENERGY DEMONSTRATION AGREEMENT

The availability of secure and affordable energy supplies is a subject of national concern. It is an accepted fact that our primary energy sources — oil and natural gas — are becoming less accessible and more costly. However, Canada is well-endowed with renewable and alternative resources that can provide a bridge into the future.

To this end, the governments of Manitoba and Canada entered into a Conservation and Renewable Energy Demonstration Agreement which was signed May 9, 1980 and terminated March 31, 1984. The Agreement was dedicated to the development and demonstration of conservation and renewable energy technologies. Equally cost-shared by the provincial and federal governments, the program had a total budget of $18-million.

The objectives of CREDA are:

- To develop and demonstrate promising new technologies, which, when widely adopted, will exploit renewable resources, conserve energy and/or use energy more efficiently.
- To develop broad public awareness of the potential of renewable energy and conservation technology.
- To provide opportunities for the commercial application of the technologies within Manitoba.
- To create economic spin-off benefits for manufacturing, industry and commerce.
- To create employment in new or existing energy-related industries.

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EXECUTIVE SUMMARY

Most commercial sized laundries vent their direct-fired natural gas dryers directly to atmosphere.

The energy recovery system installed at Perth Services Ltd., Winnipeg, extracts heat from the hot dryer exhaust air (80 to 95°C) to preheat outside air. This preheated air is then directed back to the secondary combustion air inlet of six dryers.

The system consists of two stages of lint filters, booster exhaust and supply fans, recirculation damper, an air-to-air heat pipe heat exchanger, dryer dampers, ductwork and automatic controls (see System Flow Schematic - Figure 1).

Because of the inherent dryer design and the consequent uncontrollable air leakage of the dryers, the heat recovery system's projected savings were reduced by about 50%.

During start-up, many changes were made. The exhaust dampers were modified to reduce lint build-up. The number of moving parts of the first stage lint filter was reduced. The dryer air leakage areas were sealed. The air supply to the secondary combustion air inlet was increased. A damper on the main supply air plenum for direct plant make-up air supply was added. (Refer to Section 4.1 for details.)

From dryer tests and natural gas bill analysis, the estimated annual savings, including labour savings, operating costs, and energy savings are $12,200. The cost of the system including engineering and the start-up modifications was about $130,000 (10.6 year simple payback) without the CREDA contribution and $67,500 (5.5 year simple payback) with the CREDA contribution.

RÉSUMÉ ADMINISTRATIF

Dans la plupart des laveries automatiques, l'air chaud provenant des sécheuses au gaz naturel à alimentation directe sort directement dans l'atmosphère.

Le système de récupératon d'énergie installé à la Perth Services Ltd. de Winnipeg réutilise l'air chaud sortant des sécheuses (80° à 95°C) afin de chauffer d'avance l'air de l'extérieur. Cet air est ensuite dirigé à l'entrée d'air de la chambre de combustion secondaire des six sécheuses.

Le système comprend des filtres à charpie en deux étages, des ventilateurs introducteurs et extracteurs supplémentaires, un registre de recirculation, un échangeur de chaleur air-air à caloduc, des registres de sécheuse, une installation de conduite et des dispositifs de commande automatiques (voir "System Flow Schematic - Figure 1").

À cause de la structure innérente des sécheuses et de la fuite d'air incontrôlable qui en résulte, les épargnes prévues attribuables au système de récupération de la chaleur ont été réduites d'environ 50 %.

De nombreux changements ont été effectués peu après la mise en marche du système. Les registres d'évacuation ont été modifiés pour réduire l'accumulation de charpie. Le nombre de pièces mobiles dans le filtre à charpie de premier étage a été diminué. Les issues par lesquelles fuyait l'air des sécheuses ont été scellées. Le montant d'air réservé pour l'entrée d'air de la chambre de combustion secondaire a été augmenté. Un registre a été ajouté à la chambre principale de distribution d'air afin qu'il y ait une source directe d'air de compensation pour la laverie automatique. (Pour plus de détails, reportez-vous à la partie 4.1.)

Selon les essais qui ont été faits et l'analyse des factures de gaz naturel, les épargnes annuelles, c'est-à-dire les économies de main-d'oeuvre, de frais d'exploitation et d'énergie, s'élèveront, prévoit-on, à environ 12 200 $. L'installation du système, en tenant compte de l'étude technique et des modifications apportées après la mise en marche a coûté environ 130 000 $.

Si l'on ne tient pas compte de la contribution de 67 500 $ du Programme de démonstration des énergies renouvelables et des économies d'énergie, la période de récupération simple des frais est de 10,6 ans. Par contre, si l'on en tient compte, cette période est de 5,5 ans.

1.0 CONCLUSIONS

Because of the sophistication and uniqueness of the heat recovery system, modifications were anticipated after the system was constructed. However, the extent of the modifications was far in excess of expectations and stretched over a 12 month period. Although the system design is sound, the inherent dryer characteristics and lint caused the major problems. The main conclusions are:

1.) Dryer air leakage reduced the projected savings by about 50% making the system uneconomical without a CREDA contribution.

2.) The quantity and characteristics of lint require special attention to filtering, duct systems and maintenance requirements.

3.) The first stage lint filter removes 90 to 95% of the total lint and consequentially extends the life and reduces operating cost of the second stage lint filter media.

4.) A minimum of 25% of the dryer exhaust air can be recirculated back to the dryers without any significant effects on drying periods.

2.0 RECOMMENDATIONS

The main recommendations are:

1.) Before a similar process-to-process dryer heat recovery system is attempted, the extent of dryer air leakage must be determined (see Appendix A for recommended air measurements).

2.) If the dryer air leakage is excessive then one of the following heat recovery systems is recommended (see Appendix B for details of other dryer heat recovery systems):

- preheat process water with water coil,
- mix dryer exhaust air with outside air and use as plant make-up air,
- recirculate the exhaust on each individual dryer.

3.) Two stage lint filtering are recommended to reduce operating costs of the second stage filter and prevent the heat exchanger from clogging if one filter stage ruptures.

4.) Avoid horizontal ducts and keep exhaust air velocity high (2 000 fpm) to prevent lint from building up in ductwork.

5.) Reduce operating time of dryers once heat recovery system is installed. Tests indicate that drying time can be reduced by as much as 50%. This can be done automatically if moisture controls are retrofitted into the dryers.

6.) Downsize the heat exchanger by recirculating 25% of the dryer exhaust air.

3.0 INTRODUCTION AND BACKGROUND

The Conserver Group Inc., a Winnipeg energy engineering firm of consulting electrical and mechanical engineers, designed a process-to-process exhaust heat recovery system for the direct-fired natural gas dryers at Perths Services Ltd., Winnipeg.

The system was the follow up of a detailed study entitled "Energy Recovery From Commercial Laundry Dryer Exhausts Component Evaluation and Case Study" completed in December 1980 by Mr. Brian Gaber of The Conserver Group.

The original study was based on a heat recovery system at Perths and many of the systems and components discussed in the study were used in this unique system.

The system as discussed in Section 4.0 and shown on Figure 1 consists of lint filters, booster exhaust and supply fans, a heat pipe heat exchanger, dampers, ductwork and controls. The exhaust from six dryers are diverted through a heat pipe heat exchanger via two stages of lint filtering before exiting to atmosphere. Previously the dryers exhausted directly to atmosphere. Outdoor air is passed through the other side of the heat exchanger and is delivered directly into the combustion chamber of the dryers.

The following background information on Perths will be useful in understanding some of the concepts and terminology used throughout this report.

Background

This commercial laundry washes approximately 150,000 lbs of laundry/week and includes laundry for hospitals, garment and mat rentals, restaurants, meat packaging, etc.

The majority of the laundry is processed as follows:

1) the laundry is washed in either washers or washer-extractor machines,

2) sling loads are routed either directly to the ironers (as in the case of the washer-extractor) or to extractors which hydraulically squeeze most of the water out of the sling load,

3) the laundry is either fully dried or condition-dried to an approximate moisture retention level before going to the ironers.

The fully dried laundry goods are towels, vinyl mats, mops, fluff work (wearing apparel), garment rentals, wipers, meat shrouds, pajamas, etc., which are packaged directly.

Cotton laundry sheets, family work, white work (table cloths, aprons), etc., are conditioned to approximately a 30% moisture retention (i.e. 100 kg dry weight of clothes will contain 30 kg of water) and then ironed to a wrinkle free full dry state.

The larger dryers in this plant have a capacity of either 91 (200 lb) or 182 kg (400 lb) dry weight, and are from a variety of manufacturers such as Smith Grantham, Norman, Challenge Cook, and Huebsch. Most of these exhaust into a screened gazebo type of structure, located on the roof, in an attempt to collect the lint.

From tests and observations, the dry bulb temperature and relative humidity conditions of the exhaust was found to vary from 77°C db to 107°C db and 10% Rh to 6% Rh depending on the particular dryer or on what part of the cycle was observed. The dry bulb temperature was low at the start since the dryer body, approx. 4,500 kg (10,000 lbs), and the laundry had to reach operating temperature. The relative humidity started high (approximately 10%) and gradually reduced depending on whether the load was being conditioned or fully dried. The exhaust temperature was also found to be dependent on the size of the load being dried - a large load obstructs tumbler air movement and hence traps more heat and reduces the rate at which the exhaust temperature climbs.

Drying times are affected by the size of the load, type of load, and outside air conditions. Obviously the larger the load the longer it takes to dry. Outside air that has a high moisture content can greatly increase drying times. Also winter periods necessitate the closing of many building openings thereby starving the dryers of adequate air supply even when the air make-up unit, which is undersized in this plant, is in operation.

The duration of the drying cycle is controlled by manual timers. These are usually set between 5 and 20 minutes for conditioned loads based on the operators s judgment which includes the type of load being conditioned, size, plant air humidity, etc. The setting is approximately 30 minutes for full dry loads for towels and 60 minutes for full dry for mats or mops. Cool down time on full dry loads can vary between 5 and 20 minutes depending on the size and type of load.

4.0 SYSTEM DESCRIPTION

The Perths dryer exhaust heat recovery system is shown in the flow schematic (Figure 1).

A total of six dryers are connected to the heat recovery system:

4 - 200 lb. Smith Grantham gas dryers
1 - 400 lb. Challenge Cook gas dryers
1 - 50 lb. Huebsch steam dryer

Prior to installing the heat recovery system, dryer exhaust was vented directly outdoors and replacement air infiltrated through doors and other openings for most of the year, except for 2 or 3 winter months when a direct-fired natural gas make-up air unit was operated.

The purpose of this new system is to extract heat from dryer exhaust air and use it to heat incoming outside air that is fed into the dryers, thus eliminating the need for make-up air. Because the air is fed directly into the dryer, this system will recover heat year round, which enhances its payback.

When any one of these dryers (except the small steam dryer) is operated, the heat recovery system is automatically started up. Each dryer has a set of dampers that diverts the dryer exhaust through ductwork to the heat recovery system. Another set of dampers allows preheated outside air from the heat recovery system to be drawn by each dryer into their secondary combustion chamber. On the cool down mode of each dryer, the supply air dampers reposition so that plant air is used to cool down the laundry prior to removal. The exhaust continues to be delivered to the heat recovery system for re-use in other dryers that are in the drying mode.

The dryer exhausts are collected through a network of ductwork and passes through two stages of lint filters, a booster exhaust fan and a heat pipe heat exchanger prior to exiting to atmosphere.

Ductwork

The ductwork was sized to maintain a high air velocity to reduce lint buildup in horizontal sections. Also many access doors were installed to facilitate cleaning which is done about once per month.

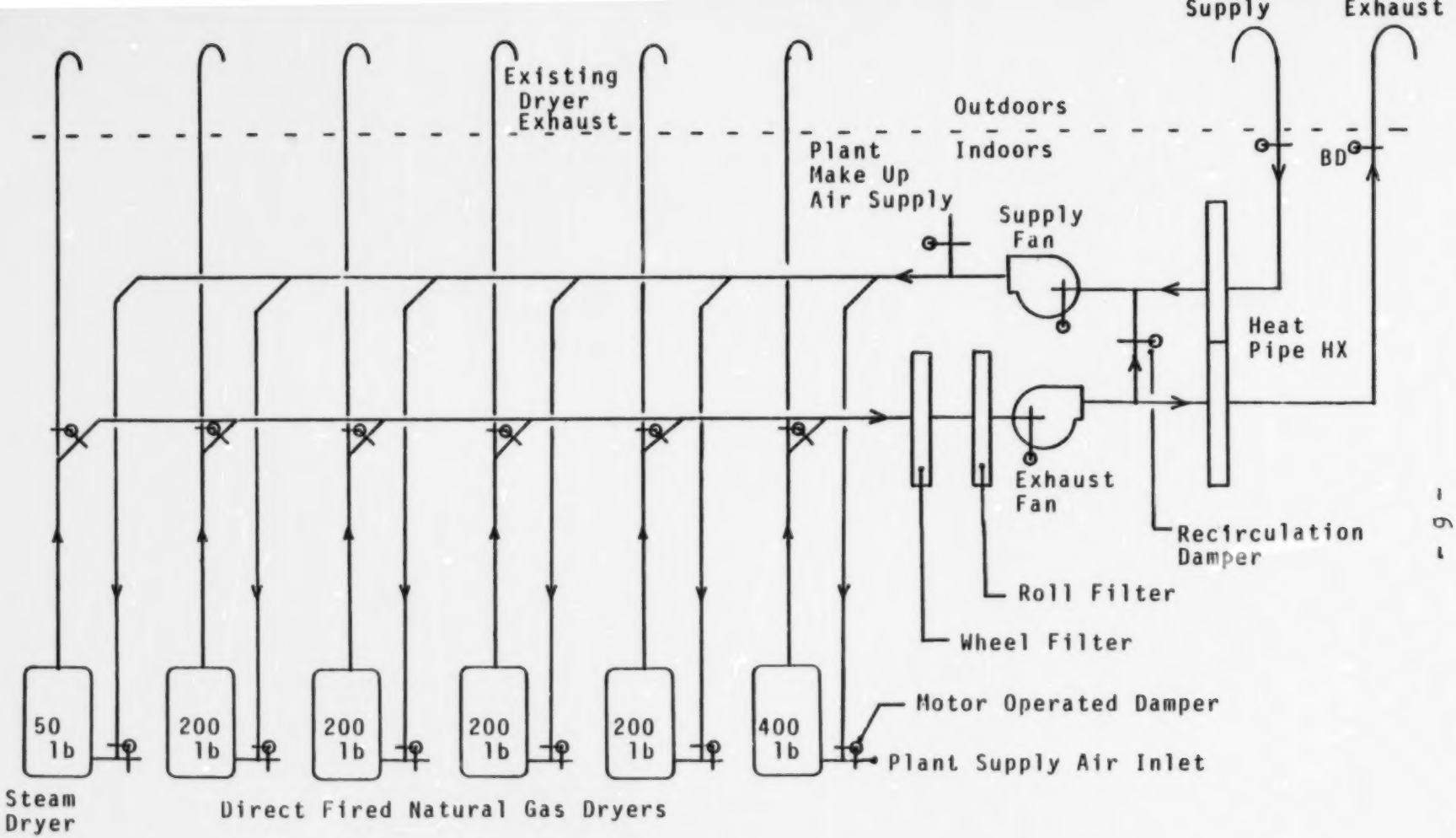


Figure 1
Dryer Exhaust Heat Recovery System Flow Schematic
Perth Services Ltd. 1860 King Edward Street

Lint Filters

The first stage lint filter was designed by The Conserver Group to reduce the operating costs of the second stage filter. The filter consists of a 2.4 meter diameter wheel with a stainless steel mesh screen The wheel rotates on a signal from a differential pressure controller at a rate of about 1 revolution per minute. The lint is allowed to build up to about a 12 mm thickness since lint itself is an excellent filter media. As the wheel rotates, the lint is pushed against a scraper which rolls the lint. The lint then falls by gravity into a collection bin where the lint is removed each day. It was estimated that this wheel filter stops about 90-95% of the lint. Approximately a 7 ft^3 (0.2 m^3) of lint is removed each day from this prefilter collection bin.

The second stage of filtering consists of two 1.2 by 2.4 meter automatic roll filters side by side. These use a white spun bonded non-ravelling nylon media (see figure 2 below). The roll filter rotates on a signal from a differential pressure controller that senses the pressure across the filter media When the pressure reaches 250 Pa, the media rotates to a clear section until the pressure drops to about 200 Pa. The media renewal rate is about 600 mm per hour. As the filter rotates, the lint laden media is rolled onto the lower roll which has to be cut and removed every 2 or 4 weeks. This filter essentially stops all lint that passes through the first filter.

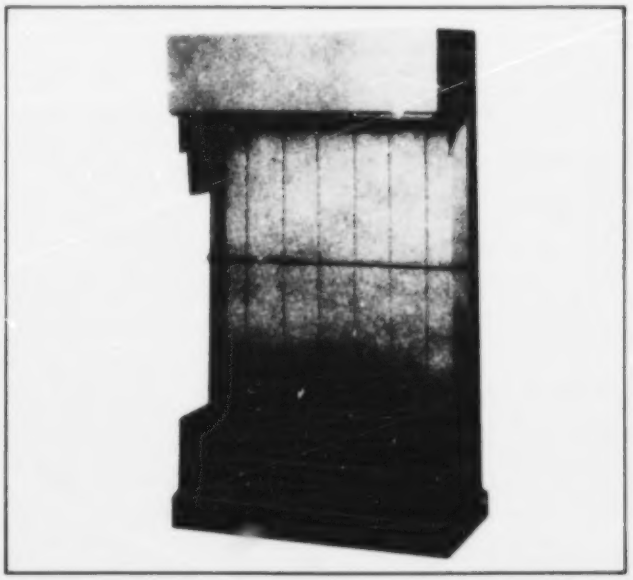


Figure 2 - Second Stage Filter (1 Section)

Exhaust Booster Fan

A 30 horsepower air foil booster fan with inlet volume control to handle up to 30,000 cubic feet per minute (CFM) of exhaust air is used to overcome the additional air resistance of the dampers, ductwork, filters and heat exchanger. As additional dryers are energized, the fan air volume increases to maintain normal dryer exhaust pressures of about 125 Pa.

Heat Pipe Heat Exchanger

A 1.5 by 4.7 m, 7 row heat pipe air-to-air heat exchanger is used to extract heat from the dryer exhaust at approximately a 70% effectiveness to preheat counterflowing fresh air (see figure 3 below). The exhaust and supply air sides are separated by a partition that is designed to prevent cross-examination of the air streams. The heat pipe consists of individually sealed pipes containing a heat transfer fluid. The exchanger is at a 10° slope with the hot exhaust side being on the lower end. As the heat transfer fluid in the sealed pipes warms, it evaporates (taking in heat) and the resulting vapour flows to the upper supply end where it is cooled by incoming fresh air. The vapour condenses (giving up heat) and the liquid heat transfer fluid flows back down to the exhaust side thus completing the continuous evaporation/condensation cycle.

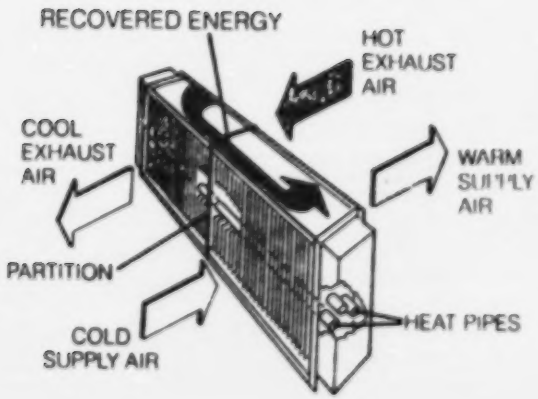


Figure 3 - Heat Pipe Heat Exchanger

Supply Booster Fan

A 20 horsepower air foil booster fan with inlet volume control to handle up to 21 600 CFM of outside air is used to overcome the additional air resistance of the heat exchanger, ductwork and balancing dampers. As additional dryers are energized, the fan air volume increases to maintain normal dryer inlet air pressure of 0 to -50 Pa.

Recirculation Damper

A motor operated recirculation damper between the exhaust and supply ductwork automatically allows a portion of the hot exhaust air, prior to the heat exchanger, to mix with the preheated outside supply air. The position of the damper is controlled by a dewpoint controller that samples the supply air and maintains the supply air humidity at a preset level. This was done to ensure the drying cycles are not extended.

System Protection

The system is designed to be fail safe such that if there is any problem or malfunction (fire, system overpressure, an underpressure condition, freeze condition, prefilter overpressure, etc.) the booster fans shut down, system dampers close, individual dryer supply and exhaust air dampers revert to their normal condition which allows them to operate independently of the heat recovery system.

4.1 START-UP PROBLEMS AND DISCUSSION

Because of the uniqueness of the system, filtering requirements, and the age of the dryers, there were many start up problems and subsequent modifications that delayed completion of the project.

Lint

The quantity and characteristics of lint exhausted by the dryers created a number of challenges all of which were ultimately solved.

The exhaust dampers (two per dryer) were mounted in the ductwork such that the area between the damper blades and damper frame created an ideal trap for lint. The lint built up in this area and many of the dampers couldn't fully close. The problem was solved by installing a triangular shaped iron channel between the damper edge and ductwork wall to create a smooth flow transition through the damper.

The rubber damper blade seals on the supply dampers (two per dryer) were falling off due to high temperatures since they are close to the dryer burner. These seals were later glued on the damper blades with a silicon adhesive. Below is a photograph showing one supply air damper and the sheet metal work around the combustion blower.

A long section of horizontal exhaust duct created a collection place for lint and could have lead to a fire. We devised and installed a lint trap in this section of duct with an increased cross sectional area to reduce the exhaust velocity and drop the lint into a collection bin. Even after internal baffles were added to try to slow the lint laden air stream, the lint traps proved ineffective. The trap was removed and a duct access door was installed for occasional clean out of lint.

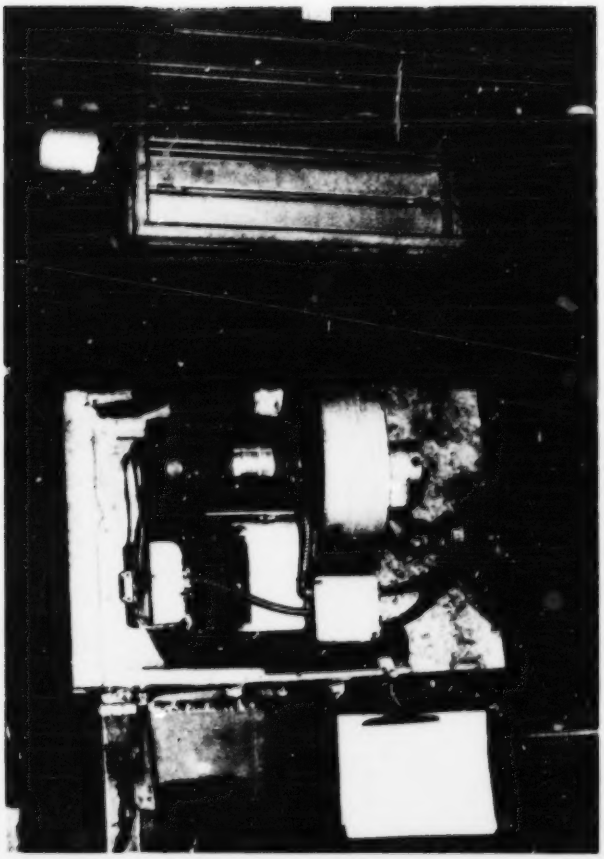


Figure 4 - Supply Air Damper

The first stage lint filter was initially designed with a conveyor-scraper system that was intended to continually scrape the lint off the screen filter and push it into a removable collection bag. Because of the 80 to 100 °C exhaust air temperatures, the drive chains stretched and eventually caused the conveyor chains to become out of synchronization. This caused the lint to jam the conveyor system and overloaded the motor, which eventually burned out. The motor-driven-chain-conveyor-scraper system was removed and a simple fixed neoprene scraper was installed. The lint now builds up against the scraper and screen and eventually drops into a collection bin which is cleaned daily.

Dryer Leakage

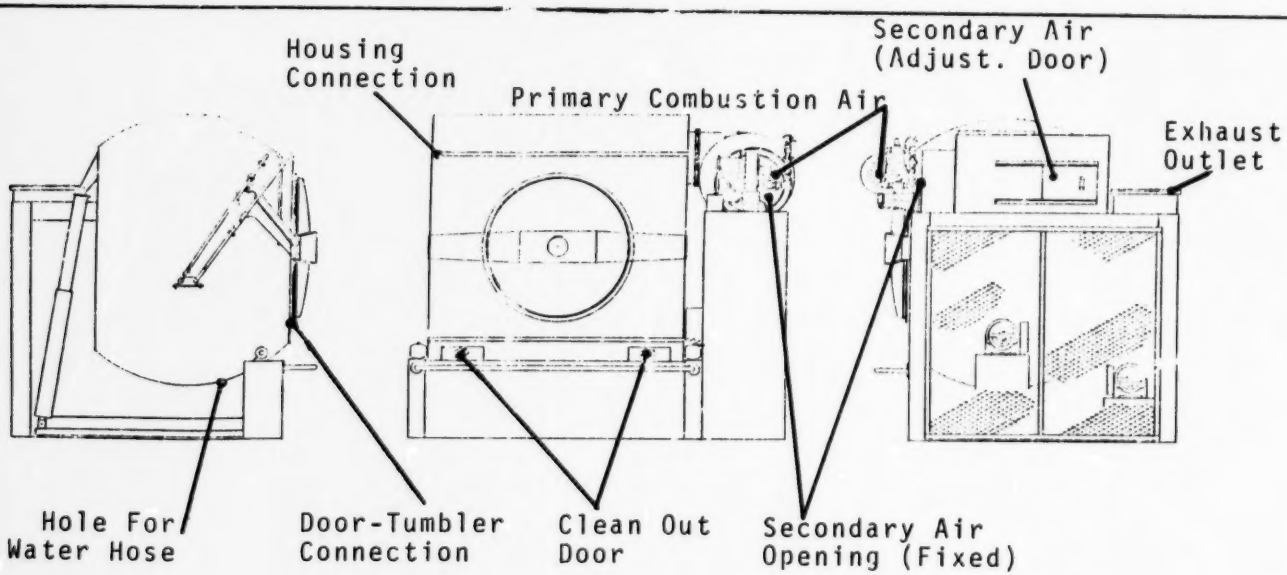
The major problem in trying to achieve the projected energy savings was due to the design of the dryers. Most of the dryers are over 15 years old and have a high degree of air leakage.

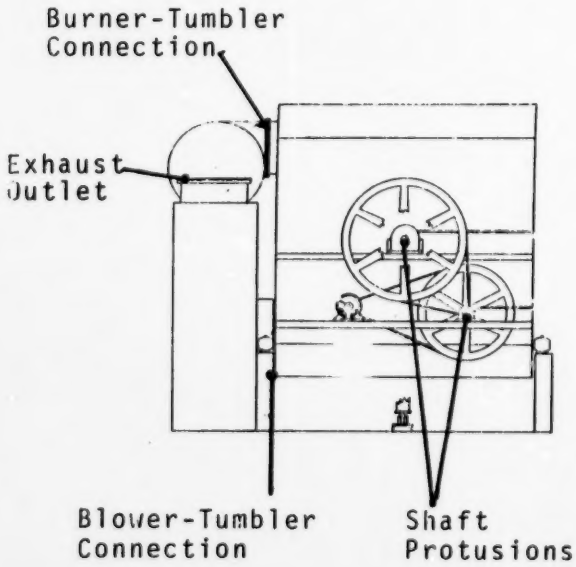
The dryer tumblers are designed to operate under a negative pressure created by their own exhaust fans. The fans draw the flame and products of combustion from the burner section through the tumbler and out the exhaust duct. Primary combustion air is supplied through a combustion burner blower while secondary combustion air enters the opening around the front face of the burner and through a door on the combustion chamber.

According to the dryer manufacturer, about 90% of the total dryer air will pass through the front face of the burner chamber. Based on this information, the supply air from the heat recovery system was ducted to the face of the dryer. However, detailed air measurement tests, conducted after the heat recovery system was installed, determined that only 40% of the total supply air enters through the front face of the burner and it did not vary whether the dryer was in the heat recovery mode or not.

We concluded that further dilution air enters from the following locations (see Figure 5 below):

Burner-Tumbler connection,
Blower-Tumbler connection,
Door-Tumbler connection,
Shaft Protrusions,
Holes in housing for water hose,
Housing connections.





Typical Dryer Air Leakage Areas

Figure 5

Due to the dryer tilting forward for unloading and backward for loading, the burner-tumbler and blower tumbler connections require a clearance to prevent jamming. The connections were built up with a flat iron and teflon plastic. However, due to past warpage of the dryer inlet and outlet ports, there still remained air gaps.

Even though the dryers had basket (tumbler) seals which are intended to seal the rotating basket at the front and back ends, the dryer enclosure still had excessive air leakage. Measures incorporated to reduce the enclosure air leakage included: teflon ring seals installed around the rotating door, lubrication access doors were taped shut, all joints were caulked, sheet metal fit around shaft protrusions and water hose inlets, etc.

After these modifications, the supply air increased to only about 50% of the total air passing through the dryer. This meant that the remainder of the air entering the dryer (plant air bypassing the heat recovery system) was from the burner and fan to tumbler connections and the primary combustion fan.

At this point it was decided to add more supply air ductwork from the heat recovery system to the secondary air opening of the combustion chamber. This was done to reduce the pressure drop in the supply ductwork in the hope that the dryer fan would draw more heat recovered air. In addition, the supply booster fan discharge pressure was increased to try to force more heat recovered air into the dryers.

This latest attempt seemed to give some improvement, however, the supply air pressure could not be increased too high as it caused the atmospheric pilots to back up in the plant and scorch control wiring.

Recently, a final step was taken in order to increase the supply air volume. Since the dryers would only take about 50% of the air from the heat recovery system, a new motor operated damper was added into the main supply air plenum allowing the remaining supply fan capacity to be utilized to reduce the negative plant pressures. This damper acts as a make-up air system in winter, delivering 25 to 35^{o}C preheated outside air. (In the summer, the damper will have to be closed to prevent overheating in the plant.) This modification will improve dryer efficiency by reducing the negative air pressure in the plant and the amount of perimeter heating due to a reduced infiltration rate.

5.0 TESTING PROCEDURES AND RESULTS

The initial monitoring procedure consisted of reading rented gas meters and recording the quantity (pounds) of laundry dried on a monthly basis. The dryers were monitored for 6 months prior and 12 months after the heat recovery system was installed. It was intended that the difference in the cubic feet (natural gas) per pound (laundry) prior to and after installation would indicate the savings achieved. However, because of the 12 months of debugging, during which the heat recovery system was intermittently operating and because of variables such as production changes, different products processed, climate, etc., it was impossible to calculate savings. Because of these variables, a number of shorter term tests were conducted as well as a natural gas bill analysis performed on the plant's make-up air unit.

5.1 WINTER ENERGY SAVINGS

1. Dryer Tests

The total pounds of laundry and natural gas consumed for four of the dryers were recorded for a two week test period; one week off the heat recovery system and one week on. The 5th gas dryer and the steam dryer were not used in the tests. The gas meter for the 5th dryer was removed in the past as it was felt that it created excess gas pressure drop which lead to flame failures. The steam dryer coils had to be repaired and the supply ductwork from the heat recovery system was not re-connected. The pounds of laundry passing through these two dryers were subtracted from the total pounds of laundry to permit a valid comparison.

Also, the weight of shop towels and mops processed was subtracted from the total. Since they emit oil vapours, the dryers are vented directly outdoors during the processing since these vapours would pass through the lint filters and could condense on the heat exchanger

Heat Recovery System Mode	Date	lbs Dried	cu.ft. Natural Gas Used	CF/lb
"OFF"	Feb. 5/85 to Feb. 12/85	82 240	159 324	1.937
"ON"	Feb. 12/85 to Feb. 19/85	81 440	151 272	1.857
			Savings	0.080

Based on a Nov. 26 to Mar. 31 winter period (about 18 weeks) average of 81 800 lbs of laundry dried per week in these four dryers and $4.576 per MCF cost of gas including 11% taxes, the energy savings will be only $600.

The dryer savings are low in winter since the temperature of the supply air from the heat recovery system is only about 5°C above the plant air temperature. However, the air going into the dryers has less moisture and should reduce drying periods.

A test was performed on typical cotton sheet loads in dryer #1 to determine if the drying cycle time could be reduced. The results were:

Heat Recovery System Mode	Dryer Cycle Time (min)	Weight Prior to Entering Dryer (lbs)	Weight After Conditioned (lbs)	Water Removed (lbs)	Water Removal Rate (lbs/min)
"ON"	6.0	186	150	36	5.5
"OFF"	6.5	198	182	16	2.5

These results indicated that drying cycle times could be reduced by at least 50% and result in substantial natural gas savings since during conditioning loads (typically 6 to 7 minutes) the dryer burner is on high fire continuously.

The dryer operators were instructed to try reducing drying times to 3 or 4 minutes for conditioning loads. After a brief test, the dryer operators felt the sheets were still too damp and have gone back to the 6 to 7 minute conditioning intervals. We cannot explain why our tests had such favourable results and the dryer operators had such poor results. However, we recommend that the dryer operators experiment further by reducing the time say by 1 minute increments, for various types of loads.

2. Make-Up Air Unit Gas Bill Analysis

The heat recovery system supplies preheated outside air directly to the plant and dryers at a total constant volume of 21,600 CFM. The delivered air temperature varies from 20° to 35°C in winter.

The plant gas-fired make-up air preheating unit is now kept off except for a couple of the coldest winter days.

Comparing natural gas meter readings between the same periods for this past winter and the previous winter:

	Natural Gas Consumption (MCF)	Average Outdoor Temperature (^{o}C)
November 26, 1983 to Jan. 30, 1984 Heat recovery system was in place but operated intermittently.	2 464	-13.4
November 26, 1984 to Jan. 30, 1985 Heat recovery system in constant use.	1 728	-12.7
Natural Gas Savings	736	

Since space heating in perimeter areas during the work day is required from mid-October to mid-April (6 months) and the make-up air unit can run from mid-November to late March, the savings of 736 MCF represent roughly 1/3 of the total space heating required due to make-up air requirements. Using 2,000 MCF as the potential energy savings, the dollar savings are about $10,000.

In addition, the electrical consumption and demand savings for not operating the 15 bhp natural gas fired make-up air unit fan amounts to $1,500.

5.2 SUMMER ENERGY SAVINGS

Dryer tests were not performed over the summer of 1984 since the system was still in the debugging stage. However, based on observations, the supply air temperatures in summer and transition months from the system to the dryers varies from 50 to 70^{o}C. Based on an average supply air temperature of 60^{o}C (30^{o}C above plant temperature), about 10,000 CFM (50% of capacity due to inherent dryer air leakage) of heat recovery supply air delivered to the dryers, a period of 34 weeks of moderate and warm weather conditions, the estimated summer savings are $4,000.

5.3 LABOUR SAVINGS

In the past, lint was cleaned out of the rooftop lint cage daily. Because of the lint filtering system incorporated into the heat recovery system, cleaning the cage on the roof has almost been eliminated. Based on an $8/hr wage cost at one hour per day to clean the cage, in the past, the labour savings are $2,000.

5.4 OPERATING COSTS

1. Energy

From current measurements, the estimated annual cost to operate the 30 and 20 hp booster fans (effectively 35 brake hp) is $3,500.

2. Labour

The heat recovery system requires some regular maintenance, including:

- removing lint from the collection bin of the first stage filter on a daily basis,
- removing lint-filled media and starting fresh media on the second stage filter every 2 or 3 weeks,
- cleaning lint from horizontal ductwork on a weekly basis.

The total estimated annual cost for this additional labour is about $900 based on an $8/hr wage cost.

3. Material

The second stage lint filter media is replaced with a new set about 3 times per year. At a $500 cost for each set of media, the total material cost is $1,500.

6.0 ECONOMIC ANALYSIS

Below is a summary of the costs and savings for the system. The total project cost of $130,000 (item D) includes engineering fees and costs of modifications during the debugging period. The simple payback varies from 5.5 to 10.6 years with the CREDA grant and without the grant respectively.

A. Annual Savings

Energy (Natural Gas at $4.576/MCF plus 11% taxes)	
Make up air gas (winter)	$10,000
Dryer gas (summer and winter)	4,600
Make-up air unit fan motor (15 bhp)	1,500
Labour ($8/hr wage cost)	
Roof lint cage cleaning (1 man hr/day)	2,000
Annual Total Savings	$18,100

B. Annual Costs

Energy (Electricity at $5.61/kVA and $0.01327/kWh plus 11% taxes)	
Exhaust and supply booster fan motors (35 bhp)	$3,500
Labour ($8/hr wage cost)	
Clean lint filters (0.3 man hr/day)	600
Clean horizontal ductwork (3 man hrs/mth)	300
Material	
Filter media (3 sets of rolls per year at $500 per set)	1,500
Annual Total Costs	$5,900

C. Net Annual Savings $18 100 - 5 900 = $12,200

D. System Cost Without CREDA Contribution $130,000

Simple Payback 10.6 yrs

E. System Cost With CREDA Contribution $67,500

Simple Payback 5.5 yrs

Recommended Air Measurements

It is recommended that before a similar system is attempted, the air leakage of the dryer be determined by air measurements.

The exhaust rate can be easily measured by performing a pitot tube traverse on the exhaust duct. However, for the air supply to the dryer, measurements are more difficult. Depending on the style of dryer, there may be numerous openings for air to enter the tumbler; burner blower inlet, front face of the combustion chamber, dilution air through openings in the side of the combustion chamber connections at the burner-tumbler and main blower-tumbler, clean out doors, external shell openings and tumbler door connection.

A sheet metal enclosure (about six feet long and the same cross sectional area as the front face of the burner opening), should be held over the opening and a pitot tube traverse performed. If the standard air volume of the supply air stream through the front face is close to 90% of the standard air volume of the exhaust air stream, then the dryer is an excellent candidate for a similar system as installed at Perths. However, if the volume of the supply is considerably lower than 90%, then the air leakage areas should be sealed and the supply volume re-measured If there are dilution air openings that can't be sealed, additional supply air duct(s) can be connected to this opening from the heat recovery system. Some openings such as the burner-tumbler and blower-tumbler connections can't be sealed effectively since most of these commercial sized dryers tilt to facilitate loading and unloading and would eventually rip any seals attempted in these areas. However, it may be possible to move the burner-blower assembly closer to the tumbler to reduce the air gap.

The dryer basket and wiper seals should also be inspected and if necessary replaced. The basket seals are designed to prevent dilution air from entering the tumbler through the tumbler-shell enclosure circumferential connections. The wiper seals, although unrelated to air leakage, are designed to direct the hot gases from the burner through the laundry mass and not short circuit back to the exhaust blower.

Other Dryer Heat Recovery Systems

If the supply air, to be recovered, cannot be increased to the 80% or 90% level, then other exhaust heat recovery options should be investigated.

a) A water coil can be installed in the combined dryer exhaust ductwork, after the filtering stages, and it could be used to preheat process water. This system is less effective than supplying the heat recovered air directly back to the dryer and also is even less effective if the laundry already has a waste water heat recovery system that preheats city water up to 30 to 40 °C.

b) The dryer exhaust air can be mixed with incoming fresh air and used as a source of make-up air to the plant thereby reducing or eliminating negative plant pressures. The Conserver Group has recently tested, through an independent laboratory, the use of direct-gas fired dryer exhaust for supplementary space heating. Once the combustion products in the exhaust are mixed with the required amount of fresh air, the chemicals in the mixture are the same or less than that of a factory approved direct-fired natural gas make-up air unit. Since this concept requires demonstration, we do not recommend it be attempted at present without the proper monitoring and control equipment. One laundry that is a potential site for the system (3 - 400 lb direct-gas fired dryers and 2 - 50 lb steam dryers) would have a simple payback of about 5 years (including engineering) without any subsidies. Of course, the other benefits co-exist with the problems in the system such as the lint problem. These problems will be cleaned up, negative plant pressures substantially reduced or possibly eliminated, and comfort improved.

c) Dryer recirculation systems could be incorporated onto each individual dryer. Approximately 50% of the dryer exhaust air could be diverted via ductwork and baffles back into the front face of the combustion burner inlet.

Initial estimates in a laundry (2 - 400 lb and 1 - 300 lb gas-fired dryers) that is presently proceeding with this method indicate a less than one year simple payback.

However, the lint problem is not solved since some of the lint will be incinerated in the combustion chamber and exhausted to atmosphere as before. Also cool down periods may be extended since on cool down mode 50% of the residual heat in the laundry and dryer mass is recirculated.